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INFORMATION CIRCULAR

FORMATION, COLLECTION, AND TREATMENT OF COAL DUST IN MINES

BY

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FORMATION, COLLECTION, AND TREATMENT OF COAL DUST IN MINES[1]

By D. Harrington[2]

INTRODUCTION

The occurrence of dust in mines has always been a source of trouble, but for many years, and virtually up to the beginning of the present century, relatively little of a definite nature was known as to the numerous ill effects of dust in mining operations. Even today, with the vast amount of time given and attention paid (for at least 40 years in various countries) to research and observation on dust in mining, and in spite of the experience with it, much information remains to be obtained before definite, well-authenticated statements can be made as to numerous features connected with the occurrence of dust in mines and of its effect upon the health and safety of the worker. One statement that can be made with relatively good assurance of being uncontradicted is that dust is a real menace to the well-being of mine workers, and this includes both health and safety. In addition, dust in and around mines and mining plants is one cause of large financial losses to mine owners and operators.

FORMATION OF DUST IN COAL MINES IN THE UNITED STATES

One definition of mining is "the processes by which useful materials are obtained from the earth's crust;" since virtually all of the useful materials of or in the earth's crust either are solids or must be reached by penetrating through solids, the materials that are moved in mining must necessarily be broken or disrupted, so that almost every phase of the work of loosening the material and transporting it is likely to produce dust.

In the earlier days of coal mining in the United States (and even to some extent at present) coal had to be won from solid strata almost entirely by means of explosives, this being termed "blasting off the solid", and almost invariably was a heavy producer of fumes and dust. Blasting now causes by all means the greatest amount of dust produced in metal mining, and blasting off the solid in coal mining is but little less productive of dust than is metal-mine blasting; in addition to producing excessive quantities

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CONFERENCE WAS POSTPONED BECAUSE
OF CONDITIONS IN EUROPE

of fine coal and of poisonous gases and smoke, blasting off the solid has been (and to some extent continues to be) an active agent in causing the ignition of either dust or explosive gas (or both) released in blasting, and in the early days of this century many coal-mine explosions had their origin in solid shooting. In fact, while blasting is not responsible for mine dustiness to any great extent now, it has been responsible directly or indirectly for the most disastrous explosions in the coal mines of the United States in the past 3 years, with 34 fatalities in an explosion in an Alabama coal mine in 1937, 45 in a Virginia mine in 1938, and 28 in a Kentucky mine in 1939, the latter two having been strictly coal-dust explosions and both having been started through carelessness with permissible explosives or the misuse of them.

With the advent of undercutting or overcutting or shearing by hand, blasting of coal became much less a producer of dust because of the greatly lowered consumption of explosives necessary to bring down the coal; and the hand-cutting process itself causes comparatively little dust. When coal-cutting machines came into the picture early in the present century to supersede in large part both hand cutting and blasting off the solid, the really heavy producer of coal dust that the worker has had to endure was at hand, and this was especially true of the chain machines operated by electricity. Top cutting is the worst offender in so far as impregnating the air with dust is concerned, shearing occupies an intermediate position, and undercutting is the least offensive in this respect. However, undercutting machi under some conditions (such as cutting dry in friable coal with dull bits in a confined place with little or no circulating air) may produce air dustiness so dense as to reduce visibility almost to zero with available types of mine lighting and to cause between 100,000,000 and 500,000,000 (or even more) dust particles to be carried per cubic foot of air of the face region.

The extension of mechanized loading has greatly increased the occurrence of dust in coal mines, not only through the considerable amounts of dust stirred into the air by the use of the loading machines themselves, but also the greater rapidity of breaking down and taking coal from the face regions speeds or increases other dust-producing processes, especially blasting, cutting, and hauling, and others to a less extent. Unquestionably the most consistent and the most prolific producer of dust in coal mining today is mechanized methods of loading; since the speed-up caused by these methods increases the release of explosive gas as well as of dust, this creates at least two additional hazards that must be safeguarded against if mechanized mining is to be done with any reasonable regard for the health and safety of the workers. In some cases the dust hazard itself is so great that open-typ electric motors are stopped at times as a precaution against possible igniti of the intense clouds of dust in the surrounding air.

Under some conditions, hand loading of coal throws into the air of the working place considerable quantities of dust, but the amount is scarcely as much as one-tenth that caused by some types of machine loading.

Hauling produces and disseminates considerable dust, but the quantity ordinarily is not as great as 5 percent of that produced by most types of machine loading or undercutting or overcutting; generally hauling by mule or horse produces greater air dustiness than does hauling by either locomotive or rope. Poorly constructed or poorly maintained pit cars or over-topping of coal in cars allow larger sizes of coal to fall off or fine material to sift through to the tracks to be ground further under the wheels of rolling equipment or the hoofs of mules and then to be thrown into the air by speeding cars or shuffling mules or men and to settle on surrounding surfaces, to constitute one of the worst dust hazards in a coal mine. This dust, when settled on surrounding timbers and other surfaces, is by far the most finely divided dust found in coal mines; usually it is much finer than 200 mesh and is much more explosive than other larger dusts. In fact, the part of an up-to-date coal mine that is probably the most difficult to protect adequately against being a constant menace towards causing or at least extending explosions, is the haulage road.

Drilling of holes for blasting has long been a prolific cause of air dustiness in metal mines, but until relatively recently it was a negligible producer of dust or of air dustiness in coal mines, especially other than anthracite mines. The hand-operated auger drill produces very little fine dust, but with the extension of mechanized mining power drills are becoming more and more essential and some of them are heavy producers of finely divided dust; this is especially true of reciprocating drills of the jackhammer type drilling dry and using compressed air in the drilling of holes either in coal or in roof or floor material.

Mining methods may cause or limit dust formation in mines. Poor mining methods or practices may result in squeezes, creeps, bumps, or other similar unsafe as well as unprofitable conditions.and cause virtual pulverization of immense quantities of coal that might have been handled in solid or lump form under better mining procedure. The driving up of large numbers of rooms and leaving the pillars to be extracted years later results in the drying out, and in some cases the breaking or crushing, of these pillars, usually with formation of large quantities of very fine dust, much of which goes into the surrounding air and ultimately on the surrounding surfaces with almost every movement of the coal to the tipple. Heavy shooting of coal to make it suitable for handling with loading machinery (conveyors, scrapers, mechanical loaders) causes much breaking into fines, and the air dustiness from mechanical handling of this coal is so intense as to constitute not only an explosion and a health hazard but also to affect safety very seriously because of lowered visibility.

Numerous other poor mining practices or methods result in abnormal production or dust in coal mines and, in addition, natural geological or strata conditions and even the climate may exert either a helpful or a harmful influence on dust production in coal mines. Some coals are naturally friable, both when in place and when broken, hence are natural dust producers; faulting may result in much fineness in the coal strata not only adjacent to the faults but also at a considerable distance from them. Some coals are so tough or so hard to break as to force the use of large amounts of explosives or of explosives of extreme breaking power with consequent heavy production of fine coal and air dustiness; some coal mines have heavy cover (up to or more than 2,000 feet), and then, unless the mining method is carefully planned and carried out, the coal is likely to crush badly, with consequent formation of fines; and numerous other natural stratigraphic conditions may intervene to intensify the formation of dust in coal mining.

Climatic conditions have a much more vital effect on dustiness in coal mines than is usually believed. In the Rocky Mountain coal-producing States (Colorado, Montana, New Mexico, Wyoming, and Utah) the air is so dry that during the entire year the coal mines of the region are being denuded of moisture by virtually every cubic foot of air circulated through them, with the inevitable result that mines in this region (except those that discover water in mining) are extremely dry and dusty, and this condition is reflected in the fact that all of these States, except Montana, had very bad explosion-disaster records until they adopted both water and rock dusting. The process of drying by air currents is used to some extent in winter in coal mines of the United States outside of the Rocky Mountain region, and corroborative evidence of the truth of this is found in the fact that the months during which widespread coal mine explosion disasters are most likely to occur in mines east of the Mississippi River are those of late winter or early spring, after the drying-out effect has reached its ultimate intensity. Conversely, in the late spring, summer, and early fall, the air entering mines east of the Mississippi River is almost always very humid as well as high in temperature (relative to the strata temperature of the coal mines), hence in those months the mines "sweat" or, in other words, moisture is deposited on their surfaces from the air currents, such deposition being heaviest in the intake air passages; but even in the farthermost portions of the mine, the air has little or no tendency to abstract moisture from the mine surfaces, as happens at all times and places in mines of the Rocky Mountain States, with their very dry climate.

Notwithstanding the fact that there is good reason for the belief that under some circumstances (only too frequently present in coal mines) air dustiness constitutes a decided health hazard, nevertheless it is going to be assumed that the objective in preparing a paper on this subject was to present information on the explosion hazard, hence only the explosion feature will be considered. Thus, any considerable reference to anthracite mines or mining is eliminated automatically from the discussion, as it has been found, both by experience in mines and by tests, that dusts of coal with less than about 10 percent volatile matter (which includes most of the anthracites) do not explode or do not in general aid in the propagation of an explosion. Hence, this paper narrows to a discussion of the explosion hazards in dusty mines where coals contain more than about 10 percent volatile combustible matte these coals include bituminous, semibituminous, subbituminous, and various types of lignite coals.

In its extensive testing work in connection with coal-dust explosibilit (see Bulletins 167 and 268, Technical Paper 84, and other Bureau of Mines publications) the Bureau of Mines has designated, and to a very large extent used, as "coal dust", material that passes through a 20-mesh sieve; and it has been found that the explosibility is proportionate to the percentages passing through sieves of finer mesh, especially 100- and 200-mesh sizes. It is recognized that rarely, if at all, will coal dust consisting only of approximately 20-mesh size ignite and start an explosion, yet there is very good reason to believe that when an explosion has obtained a good start from gas or from fine or almost pulverized dust, or from both gas and fine dust, coal particles appreciably larger than 20-mesh size participate in extending the explosion. There is absolutely no question but that finely divided (material with large percentage through 100 or 200 mesh), fairly dry coal dust that has volatile combustible above 10 percent will, when in air in a dense cloud and brought in contact with an open flame, ignite and burn with explosive violence. Moreover, tests by various governmental agencies such as the Bureau of Mines in the Department of the Interior and the Bureau of Chemistry and Soils, Department of Agriculture, as well as field experience in industrial work, prove conclusively that many finely divided dusts other than coal dusts will, when subjected to flame of sufficient intensity, ignite with explosive violence - such dusts, for example, as starch, grain (wheat, oats, rye), oil shale, sugar, cocoa, aluminum, magnesium, sulfur, and even dusts of certain sulfide ores in metal mines. Generally, any open light is enough for ignition, though in some instances an intensely hot flame is necessary.

To explode, coal dust must be mixed with air in a comparatively dense cloud. The coal dust-air mixture, when in contact with an open flame, ignites with a violence virtually proportional to the volatile combustible matter in the coal as well as in proportion to coal fineness, dryness, and freedom from impurities such as ash or similar incombustible, external moisture, and the like. Although there must be a dense dust cloud at the point of ignition, there need not be any considerable quantity of dust by weight or volume to bring about a dust ignition and explosion.

By experiment it has been found that a dust cloud of comparatively pure, fairly high-volatile, finely divided bituminous coal in the amount of one-fortieth of an ounce of coal dust per cubic foot of air is about the least dense coal-dust cloud that will propagate or extend an explosion; this is less than 2 ounces of coal dust to the linear foot of ordinary coal-mine entry. There are few if any coal-mine entries, rooms, or pillar workings in which there is not present several times this amount of dust.

From one-sixth to one-eighth ounce of finely divided, fairly high-volatile, pure bituminous-coal dust when in a uniform cloud in 1 cubic foot of air will explode violently and with high pressures when in contact with an ordinary open light or an electric arc. As applied to an ordinary mine entry having a cross section 5 by 12 feet, this would be equivalent to 7-1/2 to 10 ounces of dust per linear foot of entry.

In its coal-dust-explosion work, the bureau has found that 1 pound of finely divided pure coal dust per linear foot of entry with a cross section of 5-1/2 or 6 by 10 or 12 feet has been ample to propagate or extend explosions with extreme violence; this statement applies to any pure coal except anthracite and to atmospheres wholly without explosive gas.

A large amount of dust sampling has been done in rooms and entries as well as in pillaring and other regions in coal mines, and usually several pounds of dust passing 20-mesh have been found per linear foot of entry; generally at least 15 to 20 percent of the road dust passing 20 mesh will go through 200 mesh - a decidedly explosive size. No adequate method has yet been devised to obtain accurate samples of settled dusts on ribs, roof, and timbers, as these extremely finely divided, hence extremely explosive, dusts usually escape to a large extent with the air currents while sampling is being done. However, enough of this very dangerous settled dust has been obtained to establish beyond question its extreme fineness and its presence in such quantities that few if any mines that are at all dry, or in which there are any dry portions, are free of danger from initiation and propagation of explosions by this dust on ribs, roof, and timbers; this is wholly irrespective of the large amounts of dust usually found on the floor. The dust on ribs, roof, and timbers is usually the most dangerous, not only because of its extreme fineness (frequently more than 75 percent of it will pass through 200 mesh) but also because anything that dislodges this dust tends immediately to mix it intimately with the air to form the dust-air cloud that is necessar before dust can be exploded even when in contact with an open flame.

The danger from the much coarser but larger quantity of dust usually found on the floor of mine workings comes from the fact that the coarse material is crushed into fine dust by the feet of men and animals or by pit cars, mining machines, and loading machines, and is thrown into the air by the various underground operations; later on the fine dust settles on larger particles or surfaces on the floor as well as on ribs, roof, and timber, and hence is quickly available to be thrown into the air as a dangerous dust cloud when disturbed by any unusual occurrence, such as a fall of roof or coal, a wreck, or a concussion from blasting. Moreover, when an explosion is well started, the floor dust, even including some of the coarse material such as 20-mesh size or larger, enters actively into aiding the extension of the flame and violence. Hence, coal dustiness is dangerous whether on the floor or on the ribs, roof, or timbers; even the fact that the floor may be wet to the extent of being covered by water will not prevent the propagation or the initiation of an explosion from finely divided dust on ribs, roof, and timbers; nor will the absence of coal dust on ribs, roof, or timbers prevent initiation or propagation of an explosion by fine, dry coal dust on the floor

An expert in coal sizing, cleaning, and washing has stated that in coal fields of the Rocky Mountains more than 3 percent of the coal dumped from pit cars is material that will go through 48 mesh, hence would readily enter int a mine explosion; the same authority states that the amount of material passing 48 mesh as dumped from pit cars in one of the most productive bituminous coal seams in the eastern part of the United States is about 1 percent of the load; therefore, it is apparent that ordinary mining processes in mines of 1,000 tons capacity per day produce daily 10 to 30 tons of material fine enou to enter into an explosion, or enough to make 20,000 to 60,000 linear feet of mine entry dangerously dusty if the material were distributed at the rate of 1 pound per foot of entry.

Coals with volatile combustible only slightly in excess of 10 percent are likely to be somewhat difficult to ignite even in a finely divided state and in a dust-air cloud; however, such coals do ignite under some conditions and may propagate an explosion with extreme violence. Coals with high-volatile combustible, although easily ignited when in a dust cloud, will not necessarily propagate an explosion with greater violence than those in which the volatile combustible is but little more than 10 percent.

Coal-dust explosibility is proportionate to volatile combustible, fineness, dryness, and freedom from incombustible. The influence of proportion of volatile combustible present and of fineness has been discussed. It is manifest that very finely divided, thoroughly wet coal can be formed into a dust-air cloud only with great difficulty; hence, such material is virtually free of the danger of either ignition or propagation in connection with explosions. However, unless the finely divided coal dust is definitely wet, it can, under some circumstances, be thrown into the air and can then enter into explosion propagation in some cases even when about 10 percent of external water is present in the coal dust. Hence, when the wetness of coal dust is well defined or fairly close to the saturation point, there is comparative immunity from explosive ignition; on the other hand, immunity from propagation of a well-started explosion can be obtained definitely by moistening only when the "dust" is essentially in the form of mud or at or beyond saturation. Saturation of coal dust with external moisture is had when about 20 percent of external moisture is present. Fine coal in this condition is essentially mud and free from the danger of either initiation or propagation of an explosion; however, some subbituminous or lignitic coals contain 20 percent or more of water of composition, or inherent moisture, but that does not prevent them from initiating or propagating an explosion. It can readily be seen that watering methods as the sole means of preventing explosion in coal mines are likely to be ineffective unless the work is done with extreme thoroughness and with a degree of constancy of application almost impossible of attainment under present-day mining conditions. Watering methods, however, have a well-defined place in the safety of coal-mining operations in that the free use of water at and around the face region, especially on the cutting chain of mining machines, on loading, conveying, and similar face machinery, as well as on the coal piles being loaded, and on the face surfaces, tends definitely to prevent the scattering of fine dust through the air and through the mine; possibly it is even more important that the wetness of the face region may prevent coal dust from augmenting incipient gas ignitions, which are so prone to occur at or near faces, especially those at which open lights, black blasting powder, or electrical equipment are being used.

One of the features affecting the explosibility of coal dust is its freedom from incombustible matter - ash, external moisture, and the like. However, virtually no bituminous or lignitic coals are used commercially that have in themselves enough incombustible to prevent their dust from being subject to explosion ignition or propagation. The lower the proportion of volatile combustible matter in coal, the less incombustible is necessary to prevent initiation or propagation of an explosion of that coal; however, no commercially used low-volatile coals of which the volatile combustible is 10 percent or over have been found that have enough incombustible in themselves to prevent initiation or propagation of an explosion. In the dust sampling of various kinds of places in mines, the dusts at or near the face region usually have less than 10 percent incombustible, except coals in which the

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inherent or combined moisture is high. Samples taken from haulage roads and similar places in mines that have not been rock-dusted in some cases have an incombustible content of over 30 percent, and occasionally higher, owing to the mixing with the coal dust of the roof or floor material or the sand used by locomotives. Rarely, however, does a sample from mine surfaces that have not been rock-dusted show an amount of incombustible, whether of moisture or ash or both, sufficient to prevent either the initiation or the propagation of an explosion. Although for low-volatile coals a smaller percentage of incombustible is required to be present to prevent initiation or propagation o an explosion, in general at least 65 percent of incombustible should be present to prevent extensive explosions in our coal mines.

In the foregoing paragraphs it has been shown that in virtually all of our bituminous and lignitic mines the finely divided dust is explosive. Much more than enough dust is present, in a combustible state, sufficiently finel divided and sufficiently dry, either to ignite or to propagate an explosion if thrown into a dust-air cloud; and the entire preceding discussion has related to air conditions in which explosive gas is wholly absent. If explosive gas is present, the dangers are greatly augmented; for instance, if 65 percent of incombustible matter is required in the dust to prevent propagatio of an explosion in air free of methane, about 72 percent incombustible would be required if the surrounding air contained 1 percent methane; 79 percent incombustible with 2 percent methane; 86 percent incombustible with 3 percen methane, etc. Moreover, under some conditions as little as 150 cubic feet o an explosive mixture of methane and air may initiate a widespread explosion if fed enough fine, pure, dry dust immediately, a condition only too likely to be present at or near dusty working faces. An explosion initiated by methane generally has a much more violent start or "kick" than one originati from dust alone, and this violence tends to cause the formation of dust-air clouds whose ignition promotes explosions.

There are very few bituminous, semibituminous, subbituminous, or lignit coal mines that have not places (generally every place, unless the mine has been rock-dusted or much disintegrated incombustible roof or floor material is present) with dust conditions such that a coal-dust explosion may be initiated and propagated; and in general there are very few that have not readily available the means of ignition in the form of open lights, electric arcs, use of black blasting powder or dynamite, or misuse of permissible or other explosives, in firing with fuse, or in the employment of so-called bul dozing, adobe, or sand-blasting shots.

COLLECTION AND TREATMENT OF DUST IN COAL MINES OF THE UNITED STATES

The foregoing discussion indicates that very few non-anthracite coal mines in the United States are or are likely to be free of the hazard of coal-dust explosions. However, it is admitted that up to the present time lignitic or subbituminous coal mines in the United States have been virtual devoid of well authenticated widespread coal-dust explosions, even though experimentally the dusts of these coals are readily ignitable with resultan violent explosions. Unquestionably our mining people who operate non-anthra coal mines should at all times recognize this hazard and take feasible precautions.

Outside of removing from the mine all coal sizes fairly readily available for loading (including coal cuttings or bug dust), this being the policy of the great majority of the coal producers of the United States, relatively little is done towards collecting dust, except indirectly; and some coal-mining operations shortsightedly leave coal cuttings in the mine. Some mines cut the coal in "bone" or other refuse beds, either along the floor or at some horizon above the floor, and then shovel the resultant cuttings (largely finely divided coal) into the gob because of the unsalability of the material, which thence forward remains as a menace as regards feeding a possible explosion or causing spontaneous fires. In some cases machine cuttings of virtually pure coal are left in the mine because of lack of demand for small coal sizes, and the hazards from these are even greater than from the cuttings from refuse beds or seams. Leaving coal cuttings in a mine usually is opposed by State inspection forces, and in some instances this obvious hazard is overcome in part by applying extra amounts of rock dust to those parts of a mine that contain the abandoned cuttings.

Some experimental work has been done in the mines of the United States on the use of exhaust or suction methods to remove dust from coal-mine surfaces and mining equipment; an even smaller amount of work has been done on filtering methods and on wetting agents other than watering or sprinkling. However, in general, procedure in the United States with regard to protection from the dust explosion hazard has been along the lines of preventing ignition of gas or dust, allaying dust by watering, and diminishing its explosibility by rock dusting. Judged by results, it would appear that the policies pursued by the coal miners of the United States in this matter are at least partly successful; there wasn't a major explosion disaster in any coal mine in the United States in the fiscal year ended June 30, 1939, and but 16 persons were killed in that year in minor explosions of gas or dust, which compares most favorably with 1907, when 911 persons were killed in major and minor explosions in the coal mines of the United States. Coal production in 1907 was about 477,000,000 tons and in the past fiscal year about 400,000,000 tons.

The two main procedures in the coal mines of the United States in trying to minimize the harmful effects of dust are humidifying or watering and rock dusting. Watering methods were in more or less general use in the coal mines of some of the Rocky Mountain States as early as 1890 and were in fairly general use in Utah after the Winter Quarters explosion of May 1, 1900, proved beyond doubt that coal dust could be ignited and cause a widespread explosion disaster even when absolutely no explosive gas is present. That the Utah method of using water to prevent widespread explosion disasters produced good results when kept in effective use with unrelaxed vigilance is shown by the fact that from the date of the Winter Quarters explosion (after which watering methods were used widely and fairly constantly in Utah's coal mines) until the Castle Gate disaster in 1924, or nearly a quarter of a century, Utah had no major coal-mine disasters, though the coal dust is highly explosive (volatile matter running uniformly over 35 percent and up to 45 percent) and many of the mines become decidedly gassy. Various forms of humidifying were used from time to time and with varying degrees of effectiveness in a relatively few coal mines of various parts of the United States until the disastrous explosions at Dolomite, Ala., Dawson, N. M., and Castle Gate, Utah, in 1922, 1923, and 1924, proved conclusively that watering, even though effective when constantly and efficiently applied, was entirely too undependable.

Until about 1924, relatively little really effective rock dusting was done in the coal mines of the United States.

The most effective impetus to the spread of rock dusting in the coal mines of the United States was given by the Castle Gate, Utah, disaster in the spring of 1924, with the adoption of the so-called drastic Utah regulations a few months later, requiring (among numerous other provisions) rock dusting as well as watering in all Utah coal mines. Up to the present time all of the State laws and regulations that relate to rock dusting (and 11 States have rock-dusting requirements of some sort) couple watering and rock dusting in some manner. And the Federal Bureau of Mines, through its Mine Safety Board, recommends "rock dusting all coal mines except anthracite mines in one decision and, in another decision, that "the coal face and the working place, 40 feet therefrom, shall be kept free of coal dust by the use of water

While rock dusting has been done in a really efficient manner in probab fewer than 100 mines of the approximately 6,000 coal mines of the United States and has not been done in any manner or to any degree in more than two thirds of the coal mines of our country, nevertheless it has had a decidedly important effect in diminishing the severity of explosions of gas and dust i the coal mines of the United States. This is indicated by the fact that in the 5-year period of 1921 to 1925, inclusive, or just prior to the use of rock dust in the coal mines of the United States, the average annual loss of life from gas and dust explosions in the bituminous coal mines of the United States was 296, and for the period 1931 to 1938, inclusive, or for the past 8 years, during which rock-dusting practice has been fairly well systematize the number of gas and dust explosion fatalities was reduced to 56 per year, reduction of 240 fatalities per year as compared with the period 1921 to 19 Fairly accurate data taken from studies of individual coal-mine disasters indicate that at least 200 lives per year have been saved by rock dusting i the coal mines of the United States for the past 10 years or more, and this has been accomplished notwithstanding the fact that only 11 of our 26 coal-producing States have any requirements as to rock dusting, and that fewer than 5 percent of the coal mines of the United States can be considered as being adequately rock dusted.

Use of water at and around the working faces (on the cutting bar of mining machines, on coal piles before shoveling or loading, on loading machines or conveyors, on tops of loaded cars before they leave the working place, and on ribs, roof, and floor for at least 40 feet from the face), also use of water on the floor of main haulageways, with rock dusting of al other accessible dry surfaces (and sealing of inaccessible, unused parts of mines) together with the maintenance of active circulation of pure, fresh a urrents throughout mines and restriction or absolute prohibition of open lames (including smoking materials) or electric arcs, will ultimately solve he combined health-safety problem in coal mines as regards prevention of idespread explosions and fires, as well as in the avoidance of diseases of orkers through breathing of harmful quantities of dust. Moreover, the ntroduction of mechanized contrivances at working faces to accelerate and therwise facilitate the breaking down and loading out of coal, makes it mperative that watering methods be used at and near the face region, because hese new methods intensify the throwing of dust into the air, this being in ome cases so serious as to decrease visibility so much that not only is the afety of the workers seriously menaced but also the efficiency of the work s greatly decreased.

Watering methods alone have failed in the prevention of widespread isasters in the mines of the United States, chiefly because of neglect to eep them in full effect at all times. Rock dusting has also failed in some nstances, even in mines that have been more than ordinarily well rock dusted here the work was done inadequately in some places or not kept in effect in ome places or under some conditions. Hence, neither rock dusting nor watering alone will prevent mine explosions; however, experience in the United tates indicates that a combination of the two unquestionably gives the best rotection now known against the occurrence of widespread explosion disasters. hat our program in explosion-disaster prevention is not far from being ffective is at least indicated by the fact that the number of deaths from ajor explosions in the coal mines of the United States decreased from an verage of 477 per year from 1906 to 1910, inclusive, to 48 per year for the ast 6 years, 1933 to 1938, inclusive.